THE GLOBAL ENERGY AND WATER CYCLE EXPERIMENT SCIENCE STRATEGY

Moustafa T. Chahine
Jet Propulsion Laboratory
California Institute of Technology

The distribution of water in the atmosphere and at the surface of the Earth is the most influential factor regulating our environment, not only because water is essential for life but also because through phase transitions it is the main energy source that control clouds and radiation and drives the global circulation of the atmosphere. As such, the hydrological cycle is the main vehicle that links all major processes in the climate system.

The Global Energy and Water Cycle Experiment (GEWEX) is an element of the World Climate Research Programme and began in 1989 to observe, understand and model the hydrological cycle and energy fluxes in the fast component of the climate system (the slow component contains the "memory" of the ocean heat storage and circulation) . The goal of the GEWEX research program is to predict variations of global hydrological regimes and the impact of these variations on atmospheric and ocean dynamics. Ultimately, skill in this area will lead to the ability to predict how regional hydrological processes and water resources will respond to changes in the environment. In areas such as the Mississippi Basin, the Baltic Sea, the Mackenzie River basin, Amazonia and the monsoon regions in Asia, GEWEX is conducting regional-scale observational and modeling programs to accelerate this area of research.

In support of reaching the goal of the program, GEWEX is pursuing studies in three focused areas which are addressed during this symposium:

First, GEWEX is improving skill in the prediction of precipitation and changes in water resources and soil moisture over continental regions. This is a significant contribution toward improving seasonal–to–interannual climate predictability. Demonstrating the capability to predict floods and drought months in advance would be a great scientific achievement and would have enormous commercial. and economic impact.

GEWEX is developing a variety of techniques using existing or new data sources and data assimilation products to estimate area and time-averaged precipitation and evaporation on the global domain. Recent research has pointed to the need for increased temporal resolution in observations of precipitation. Both the water balance and estimates of net primary productivity are sensitive to the temporal resolution of precipitation. Sato and Nishimura (1995) showed that, as longer time averages of precipitation are taken, runoff becomes smaller and evapotranspiration becomes larger. The highly nonlinear processes governing soil hydrology and carbon assimilation in vegetation (Hubert et al, 1.995) are illustrated by comparing model predictions of vegetation net primary productivity using daily rainfall (Fig. lb) to predictions using monthly rainfall (Fig. la). In response to results like this, the GEWEX Precipitation Climatology Project is moving toward providing a data set at higher temporal resolution.

Second, the radiation budget and fluxes in the atmosphere and at the surface are being determined with improved accuracy. These determinations support the modeling of the response of the climate system on various time scales to changes in anthropogenic forcing. GEWEX radiation studies bring together theoretical and experimental insights into the radiative interactions and feedback of clouds and water vapor with the Earth's ocean and land surfaces.

(a) (b)

Figure 1. Annual Net Primary Productivity (NPP) (kgCm^{-2}yr^{-1}) calculated with monthly rainfall (Fig. la) is significantly underestimated (-32%) compared to NPP calculated with daily rainfall (Fig. lb) . (Hubert et al, 1995)

The IPCC 1995 report (IPCC, 1996) states that "Warmer temperatures will lead to a more vigorous hydrological cycle; this translates into prospects for more severe droughts and/or floods in some places. . . " . Increases in greenhouse gases not only increase surface temperatures through an increase in atmospheric downwelling infrared radiation (primarily due to increased water vapor) , but also may enhance the hydrological cycle through increased evaporation and the increased water-holding capacity of the atmosphere. The mean residence time of atmospheric water vapor, or its recycling rate, can be determined on a monthly basis. A shortening of the recycling rate may indicate an accelerating hydrological cycle. Chahine et al (1997) calculated the observed recycling rate per month, defined as the ratio of the total monthly precipitation over the (steady state) mean precipitable water vapor for the same month. The resulting zonal average recycling rates per month are shown in Figure 2, for a grid size of 2.5 x 2.5 degrees. The large range of variations of the recycling rates, apparently due to the influence of the land masses in the northern hemisphere, are clearly visible. An extended period of observation will be needed before conclusions can be drawn on any trends.

Trenberth (1997) cautions that the intensity and frequency of rainfall must be examined, not just accumulated amounts. If rain rates increase faster than rain amounts, then the frequency of rain could decrease even with increased atmospheric moisture amounts. More intense rainfall events could increase the risk of flooding in some parts of the world, while less frequent rain events would be very disruptive to agriculture. Determining how the hydrological cycle will respond to increased greenhouse gases requires significantly improved understanding of the various processes that govern the hydrological cycle, including the response of clouds and their effects on atmospheric column heating, as well as improved observations ancl temporal/spatial sampling of water vapor, precipitation, atmospheric temperature, and clouds.

Figure 2. Observed zonal average of the recycling rate per month of the total atmospheric precipitable water vapor for the period 1988-1994 between 60N-60S. (Chahine, 1997)

Third, GEWEX modeling and prediction studies (in collaboration with WGNE) are making use of the scientific insight from GEWEX global data sets and process studies to develop accurate model formulations of the water budget and transport and the energy budget and radiation transfer in the climate system. At present, a major remaining problem is the accuracy of parameterizing sub-grid-scale processes of clouds and water vapor in general circulation models (GCMS). The GEWEX Cloud System Study (GCSS) is promoting the use of cloud resolving models (CRMs) to evaluate and develop convective parameterizations for use in GCMs.

Recently, two versions of the ECMWF convection scheme were evaluated using data from cloud resolving model simulations of unorganized convective regimes (Gregory, 1997). Figure 3 compares the cloud amount in the CRM simulation with the standard and revised ECMWF convection schemes. The standard ECMWF convection scheme over-predicts low clouds, while cloudiness predicted by the revised scheme is in reasonable agreement with the CRM simulation.

Finally, to support the resear-ch activities of WCRP, GEWEX has undertaken the task of assembling available surface measurements and integrating them with meteorological data and satellite observations to produce climatological records of important parameters such as rainfall, river runoff, cloud characteristics, surface radiation and atmospheric humidity.

Chahine, M.T., R. Haskins and E. Fetzer, Observation of the recycling

Hubert, B., L. Francois and P. Warnat, Stochastic generation of precipitation and effect on vegetation net primary productivity, GEWEX News (May 1995).

IPCC (Intergovernmental Panel on Climate Change), Climate Change 1995: The Science of Climate Change, Eds. J.T. Houghton, F.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell, Cambridge University Press, Cambridge, UK, 572 PP (1996).

Sate, N. and N. Nishimura, Sensitivity of a simulated water budget to temporal resolution of atmospheric forcings, GEWEX News (May 1995) .

Trenberth, K.E., Atmospheric moisture residence times and cycling: implications for how precipitation may change as climate changes, GEWEX News (August 1997).